Summary of Thesis

The world has experienced unheard-of urbanization in recent years, alongside a surging number of vehicles on the street and pollution problems. Moreover, a growing cost of products is consequent on an inefficient urban distribution system. Under this context, the concept of city logistics has been brought forward. Numerous community-based applications have been performed in food distribution, the largest flows in cities, among which the creation of drop-off points serves as an intelligent method to exclude the costly last-mile deliveries and considerably reduce operating costs.

This thesis deals with a practical problem faced by Panier Futé Coop, a food distribution cooperative in Montreal North, which consolidates customer orders and deliver products to designated drop-off points rather than end customers. Savings on both purchasing and distribution processes are shared among members while the members, in return, are encouraged to contribute voluntary service to help the cooperative either in order preparation or in product deliveries. The main objective of this work is to help Panier Futé minimize the total operating costs and optimize the service times simultaneously. Conventional work includes designing the delivery routes from the central depot to drop-off points and allocating drop-off points to each driver. Different from other food distribution companies, however, there are volunteers (coop members) participating either in the order preparation at the depot or in the delivery, which makes the problem more complicated. First, the volunteers will use their vehicles other than those from the cooperative to transport goods and receive an amount of compensation for the fuel. Second, we need consider different capacities for different vehicles. Third, the volunteers' service time is limited to three hours while for the employees, the working time is eight hours. Finally, volunteers are not required to come back to the depot after having done the deliveries while the cooperative employees must return to the headquarters (the central depot), which results in a combination of closed and open routes.

To solve this problem, we adopted a quantitative research methodology. In the first stage, a mathematical model was developed, presenting the objective and constraints. Demand analysis was made for the products of Panier Futé, the customers, and the drop-off points they deliver to. In addition, an ABC analysis was proposed to categorize products and field measurement was done for the most important ones. As products are transported via boxes, a template was then developed to translate the capacity used by each order into the boxes.

As this thesis was completed in collaboration with Panier Futé Coop, field visits were conducted to understand their operating process and data were provided by the director. To solve the Vehicle Routing Problem (VRP), we used a VRP spreadsheet solver (Erdoğan, 2017), which is an open-source software available online[1]. This solver is based on a Large Neighborhood Search (LNS) heuristic and enables the solution of a wide variety of routing problems. Some customized configurations were made for this solver, while its LNS heuristic was kept as a black box. Furthermore, we developed an algorithm to allocate the order preparation work to the employees and volunteers, which in turn used the VRP spreadsheet solver (Erdoğan, 2017) to assess the cost

[1] VRP Spreadsheet Solver (version 1.05). Retrieved October 20, 2016, from http://verolog.deis.unibo.it/vrp-spreadsheet-solver

of the proposed allocation. We also analyzed two scenarios to help the decision-making on purchasing plastic boxes or cardboard boxes used for delivery. The former required that boxes be delivered back to the depot, whereas the latter did not. As the VRP spreadsheet solver (Erdoğan, 2017) allows us to evaluate two scenarios, results of different alternatives were presented. Insights were provided for the director to balance the trade-off between these two options. At the end, we measured the CO_2 emissions resulting from the transportation activities for these two scenarios to evaluate the environmental impacts.

Computational results show that feasible solutions could be obtained within acceptable computation time (from 4 to 12 minutes). In terms of the main findings, a similarity is identified in the solutions obtained from a set of 20 instances: the employees are responsible for delivering the food while the volunteers prepare orders at the depot, due to the insufficient capacity of volunteers' vehicles. This situation remains unchanged even if the fuel costs (included the fuel compensation) and salary of employees augment separately by 30%. Also, the comparison between the total cost when using plastic boxes only and that when using cardboard boxes only suggests that the distribution activities will produce less CO_2 if we use cardboard boxes. But this scenario would bring about a much higher total cost and the extra costs account for a large portion of the total distribution costs. That is the reason why we recommend the cooperative to purchase more plastic boxes when facing a growing demand in the future.

This study has a number of implications for future practices. The customized VRP spreadsheet solver is applicable not only for Panier Futé Coop but also for other similar small-sized distribution problems with order preparation processes performed by heterogeneous resources. It is helpful as well for quantifying the transportation costs so that people could better understand the processes and optimize them to reduce the total costs. In addition, the analysis of the two scenarios provides practical insights for the cooperative to evaluate the trade-off and make purchasing decision regarding the type of boxes to use. Finally, the calculation of CO_2 emissions encourages practitioners to quantify their environmental impact. We also show how one can quantify the CO_2 emissions incurred by using different packaging solutions.

Several limitations of this study must be mentioned. The computation time would be long if the number of drop-off points is relatively large and the tool would fail to solve the resulting problem. Moreover, all the measurements for product volume and preparation time are done in an approximate way. Thus, the results obtained from the template may not be very precise. Further research could be undertaken in the 3-Dimensional Bin Packing models to increase the accuracy of measuring product volume but on the other side, it is complicated and costly for this problem. The allocation of preparation time could be improved by investigating more complex algorithmic structures. One improving aspect lies in refining the preparation decisions with respect to individual customer orders, rather than aggregating orders per drop-off point. Another research direction could aim at optimally solving the problem, through the development of an adequate exact algorithm. This, in turn, would allow for designing better heuristic algorithms for the problem as well. Lastly, in line with the growing concerns on environmental issues, one could integrate emissions into the objective or study a multi-objective model.